

## Virtual Reality: An Emerging Tool to Treat Pain

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### ABSTRACT

*Excessive pain during medical procedures is a widespread problem. Pain during medivac, and during medical procedures for combat-related injuries is often not adequately controlled using pharmacologies alone. Immersive Virtual Reality (VR) is being explored in a growing number of civilian medical centers as a non-drug distraction technique to augment procedural pain control in trauma and burn patients. The feeling of pain experienced during medical treatment can be reduced through sophisticated virtual reality helmets, a simple computer game and the patients willingness to become immersed in the virtual world. The essence of VR is the illusion users have of going inside the computer-generated environment. Being drawn into another world drains a lot of attentional resources, leaving less attention available to process pain signals. Preliminary data show that rather than having pain as the focus of their attention, for many patients in VR, the wound care becomes more of an annoyance, distracting patients from their primary goal of exploring the virtual world. As a result, this type of distraction even reduces the dosage of pain medications required to make patients comfortable, which could be of great help during medevac from theater. There is a need to further assess the methodology and the psychological aspects of this technique in order to improve its analgesic property. Work is in progress to miniaturize the tool and make it applicable as close as possible to the front line for use by combat medics and forward medical facilities (NATO Role 1 and Role 2).*

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### 1.0 INTRODUCTION

Military researchers have been showing a great interest in VR for years, especially in the field of medical training, combat training, and flight training. Recently, more information has become available on the positive impact of VR interventions on pain. Planning for the collaborative development of the first immersive virtual system designed for reducing pain is now underway. Pain in burn patients is a major issue for the DoD, and VR appears to be a very exciting tool to help these patients cope with their medical treatments (e.g., burn wound debridement from burn wounds received during IED explosions in OEF/OIF). Development of the SnowWorld software has resulted in a unique product which has been used and evaluated at the Burn Unit, Institute of Surgical Research.

### 2.0 WHAT DO WE KNOW ABOUT PAIN?

Pain is an unpleasant sensation which can occur in various degrees of severity, ranging from discomfort to agony, as a consequence of injury, disease or emotional distress. Painful sensations are detected by specific receptors which inform us on the type of stimulus: it maybe a pressure, a torsion or a burn. Once the stimulus has been received by the brain and analyzed, the body gets more information on the precise location, intensity, and the duration, to help assess the damage. The feeling of pain is therefore primarily based on simple neurophysiology: a message coming from the skin, a bone or a tooth is conveyed to the brain (nociception). However, the patients perception of any given nociceptive signal from a pain receptor can be very different depending on a person's emotional state, level of attention, interpretation of pain, anticipation based on previous experiences, or expectation of life threatening consequences. Neuroimaging using PET or fMRI show that several brains areas are consistently metabolically active during nociceptive stimulations when subjective pain is reported. Moreover, inter-individual differences are visible: highly sensitive individuals exhibit more frequent and intense activations than those less sensitive.

The conventional treatment of pain has well established guidelines. Depending on its type, (e.g., chronic or acute), analgesia is based on drugs. Using over the counter pain killers such as aspirin, acetaminophen or ibuprofen have become a reflex for all us when suffering from painful conditions. When the pain is becoming unbearable, physicians would prescribe more potent drugs such as opiates. The well known problem with most drugs is that the benefit is usually accompanied by side effects which can not only be bothersome but can sometimes be life threatening. Aspirin has been shown to have detrimental effect on coagulation and can affect the integrity of the upper gastro-intestinal tract, ibuprofen in high doses can cause liver damage, and opiates are known to increase the risk of problems which have been well described in the literature. Although opioids are the cornerstone analgesic for patients with severe burn injuries and other trauma injuries (Patterson, 1992;1995; Malchow and Black, 2008), side effects of opioid narcotic analgesics limit dose levels and frequency of use (Cherney et al, 2001). Opioid side effects frequently include nausea and constipation, and opioids may reduce immunosuppression (Vallejo et al, 2004).

Considering the risks associated with drugs, researchers and health care professionals focus on another direction: is it possible to reduce pain by influencing perception. Peter Staats, MD, from the Johns Hopkins Pain Clinic has offered a couple of pointers. Patients dealing with pain must remember that focusing on pain makes it worse. They should instead try to concentrate on events or situations which make them happy, they should meditate and try to relax as much as possible, and more importantly they should have fun during painful procedures such as severe burn wound cleaning (perhaps easier said than done).

### **3.0 NEED FOR IMPROVED PROCEDURAL PAIN MANAGEMENT**

As the result of aggressive use of explosive devices against U.S. troops by enemy insurgents in Iraq and Afghanistan, thousands of U.S. warfighters have suffered severe burn wounds and/or other trauma injuries. Malchow and Black (2008) cite reports that over 80% of American casualties are transported from Baghdad to Germany with uncontrolled pain. Severe to excruciating pain often continues during hospitalization. U.S. warfighters with severe combat-related injuries—such as burned hands, broken bones, and amputations—must undergo frequent wound care sessions as part of their recovery. For patients with severe burns, wound care/debridement typically involves cleaning the wound and scrubbing dead skin away as it sloughs off the wound during healing, to help avoid infection. Debridement typically occurs daily, for weeks or months. For burn patients, physical therapy stretching of the newly healing skin helps to counteract the healing skin's natural contraction as it scars, increasing skin elasticity, and thus enhancing range of motion (Carrougner et al., 2009). Most burn patients report severe to excruciating pain during medical procedures (Choiniere et al., 1989; Carrougner et al., 2003; see also Melzack, 1990).

Solving the problem of excessive pain may prove more challenging in military populations than in civilian populations. Both physical and emotional suffering—including PostTraumatic Stress Disorder and depression—are particularly problematic in survivors of combat-related injuries caused by explosions (McGhee, Maani, Garza, Gaylord, and Black, 2008). In one recent study (Clark et al., 2009) patients who had experienced combat-related blasts had more extensive physical injuries (i.e., they were more likely to have amputations) and greater pain severity. Soldiers with combat-related burn injuries required larger opioid analgesia doses for pain than soldiers and civilians with non-blast injuries.

Repeated acute pain episodes during medical procedures and repeated daily doses of strong narcotic analgesics can interfere with healing and long term outcome. For example, excessive pain may increase the risk of developing chronic pain, and opioids can further suppress an already compromised immune system. Successful analgesia during wound debridement can enhance recovery and speed patients' return to active duty or civilian life, while reducing the costs of long-term medical care due to primary or secondary pathology (Malchow and Black, 2008). PostTraumatic Stress Disorder and depression can be exacerbated by uncontrolled acute pain during medical procedures, and similarly, these psychological disorders can amplify pain perception (e.g, flashing back to Iraq roadside bomb attack during wound care may make the wound care session more unpleasant and more intensely painful). And patients can get in a rut. For example, excessive pain on one day can increase expectation of pain the next day, leading to nocebo hyperalgesia, the functional opposite of the placebo effect (Colloca et al., 2007).

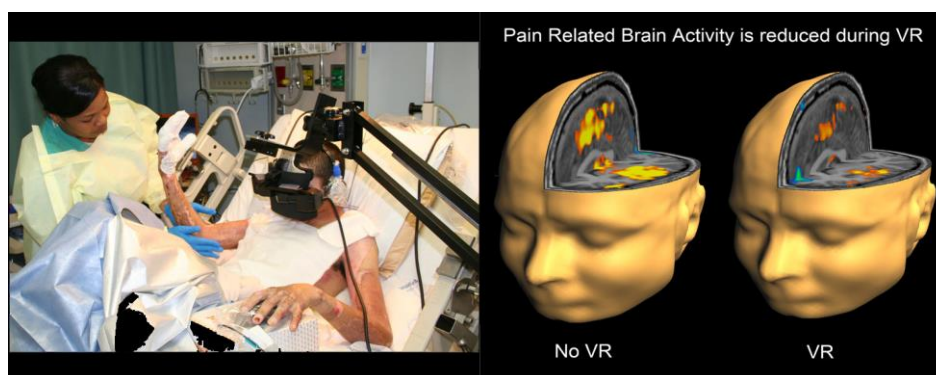
### **4.0 IMMERSIVE VIRTUAL REALITY**

Immersive Virtual Reality has the potential to decrease suffering for U.S. troops with combat-related burn injuries who must undergo painful wound debridement and rehabilitative procedures. VR is typically used adjunctively, in addition to any pain medications the patient is already receiving. Immersive Virtual Reality is hypothesized to reduce pain via a non-pharmacologic attentional mechanism (Hoffman, Doctor, Patterson et al, 2000; Hoffman, Garcia, Kapa et al., 2003; Patterson, Hoffman, Garcia, and Jensen, 2006; Hoffman, Sharar, Coda et al., 2004; Hoffman, Richards et al., 2004). Patients look into VR goggles. The goggles block patients' view of the hospital room, so they cannot see the wound care. Instead, the goggles substitute synthetic computer-generated images from an illusory 3D virtual world. Noise canceling earphones block sounds from the hospital room, and substitute more calming music and sound effects. The patient interacts with the virtual world, throwing snowballs at objects in the virtual world, which makes it even more attention grabbing. According to this logic, pain requires attention (Eccleston and Crombez, 1999), and patients have a

limited amount of attention available (Kahneman, 1973). VR draws upon these limited attentional resources, leaving less attention available to process incoming pain signals. Consistent with involvement of an attentional mechanism, burn patients report they spend much less time thinking about their pain during wound care, while in SnowWorld. In addition, laboratory pain studies have shown that on a divided attention task, where the primary task is to monitor a string of numbers, performance on the primary task drops significantly when participants go into Virtual Reality (Hoffman, Garcia, Kapa et al., 2003).

## 5.0 PRELIMINARY RESULTS

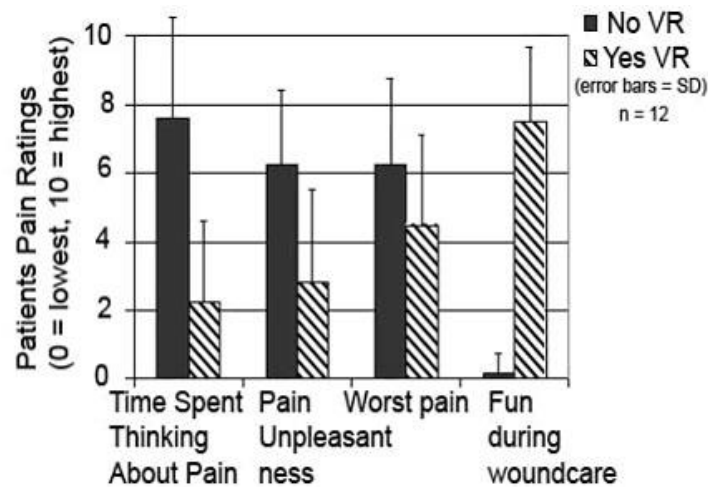
Controlled studies with civilians and recent results with military populations/combat casualties show preliminary evidence that allowing patients to “go into” Virtual Reality during painful procedures can help reduce excessive pain non-pharmacologically. Compared to standard of care (i.e., pain medications with no VR) researchers consistently find 30-50% reductions in pain ratings when VR is used adjunctively with opioids during civilian severe burn wound care (Hoffman, Patterson et al, 2008) and physical therapy (Hoffman, Patterson, Carrouger, 2000; Hoffman, Patterson, Carrouger, Sharar, 2001; Sharar et al., 2007; Hoffman, Patterson et al., 2008). Similiar results have been reported while treating soldiers with combat-related burn injuries (Maani, Hoffman, et al., 2008, see Figure 1 left). In addition, analog laboratory studies using fMRI brain scans have shown large reductions in pain-related brain activity associated with Virtual Reality analgesia (Hoffman, Richards et al., 2004, see Figure 1 right). Using a static fiberoptic VR helmet with 800,000 tiny fibers per eye, Hoffman, Patterson et al, (2008) showed that VR analgesia can reduce some of the most severe pain in medicine: during severe burn wound care/debridement in the hydroscrub tanks. Surprisingly, VR was most effective in patients who needed it the most, those with worst pain scores of 7 or higher on a scale from zero to 10 (a pattern of results recently replicated in patient with combat-related burn injuries (Maani Hoffman et al., submitted). Immersive Virtual Reality (VR) appears to show a non-pharmacologic dose-response relationship where more immersive VR systems (presumed to be more attention grabbing) reduce pain more effectively than less immersive VR systems (Hoffman, Sharar et al, 2004; Hoffman, Seibel et al., 2006). For example, in a between-groups, double blind analog pain study manipulating only helmet quality, more immersive medium field of view VR goggles led to clinically meaningful reductions in pain in 2 out of 3 participants, whereas less immersive narrower field of view VR goggles led to clinically meaningful reductions in pain in only 1 out of 3 participants (Hoffman, Seibel et al., 2006).



**Figure 1.**

Although there is preliminary evidence that immersive Virtual Reality is an effective distraction for procedural pain, commercially available VR helmets are inadequate for everyday clinical use in hospitals, and

especially for more rugged environments needed for treating military patients closer to the battlefield. Lack of a commercially available, lightweight, wide field of view high-tech VR helmet suitable for military use for VR analgesia is a barrier to widespread clinical adoption of this promising new technique into everyday military as well as civilian clinical practice e.g, commercially available conventional VR helmets cannot be used to treat patients near water, such as in the scrubtanks where some of the most painful wound care takes place, because considerable display electronics and backlight illuminators requiring electricity are mounted on the patients head with conventional VR helmets (Hoffman, Schowengerdt et al, in press).



**Figure 2: Results from 12 soldiers burned by IEDs in OEF/OIF, Maani, Hoffman et al, submitted).**

As mentioned earlier, soldiers injured on the battlefield are often undermedicated during medivac from the battlefield in Iraq/Afghanistan to Germany (Malchow and Black, 2008) and from Germany to the Trauma Center at ISR in San Antonio. Although we recommend using VR in addition to opioids, VR alone is especially likely to be effective for patients who get little or no pain medications, since VR appears to be most effective for patients with worst pain of 7 or greater (Hoffman, Patterson et al., 2008; Maani, Hoffman et al, 2008). Our laboratory studies show that VR analgesia alone is at least as effective at reducing pain as a moderate dose of opioids alone (Hoffman, Richards et al., 2007). This potentially powerful nonpharmacologic analgesic (Virtual Reality analgesia) could help compensate for undermedication during transport.

## 6.0 VR DELIVERY IMPROVEMENT

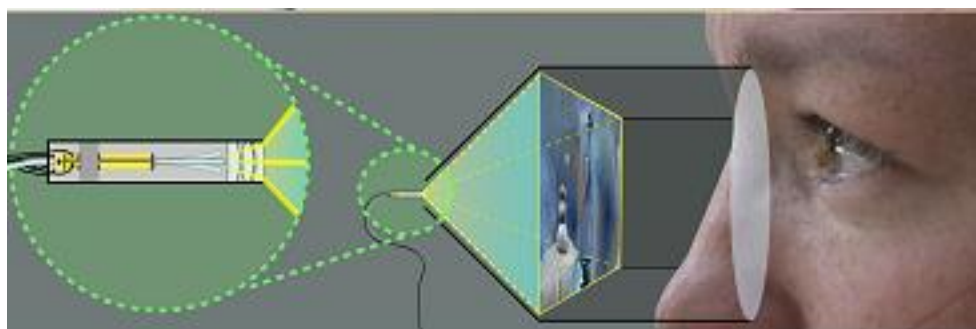
Scientists and researchers from the University of Washington in Seattle have achieved a medical/technological breakthrough in originating the technique of using of VR for analgesia (Hoffman, Doctor, Patterson et al, 2000; Hoffman, 2004). University of Washington Engineers originated the scanning fiber endoscope (Seibel et al., 2008; Seibel and Smithwick 2002). With the support of the US Army Telemedicine and Advanced Technology Research Center, Hoffman and Seibel are working to develop and test a “scanning fiber” VR helmet suitable for military trauma/burn center and Medivac use, with potential to be brought further forward into the battlefield in future projects. The proposed paradigm shift from small Liquid Crystal and related miniature displays to ultra small ultra lightweight “nearly zero heat” scanning fiber projectors as the image sources for the VR helmet will greatly increase the suitability and availability of VR analgesia in military medicine.



Because existing VR helmets present major drawbacks such as weight, heat, and cost to name a few, there is an urgent need to design and evaluate a much lighter VR helmet for reducing pain of wounded warriors during transport from the battlefield to the US Army Institute of Surgical Research (USAISR) in San-Antonio TX. Once the prototype is available, on its way more forward, it will first be used in future randomized controlled clinical studies exploring the efficacy of VR analgesia during wound debridement and painful physical therapy during injured extremity rehabilitation in soldiers with severe combat related burn injuries at USAISR. A ruggedized, cooler temperature, and much lighter weight and comfortable VR helmet that is suitable for everyday clinical use, and also suitable for use nearer to the battlefield (e.g. military transport from the battlefield to the trauma center/hospital), and that can also be used near water and in fMRI brain scanners, is widely needed for a growing number of combat casualties (not to mention military training such as dismounted infantry). Because VR uses electronics and not drugs, Virtual Reality analgesia does not cloud the injured soldier's thinking/judgment like narcotic analgesics (satisfying the military's request for battlefield interventions that do not cloud decision making).

### 7.0 THE SCANNING FIBER VR GOGGLES

Fiberoptics can be used as a remarkable conduit to carry high definition computer generated video movies/video games from the miniaturized RGB light sources to the goggles. The University of Washington project introduces a new scanning fiber display technology that is inherently small, rugged, lightweight, water friendly and fMRI magnet friendly. Hoffman and Seibel propose to introduce the first miniature, very lightweight (e.g., 1 ounce) scanning fiber projector image source for a VR helmet, to replace the heavy, hot, expensive, electronic, breakable miniature computer displays currently used in commercially available VR helmets. The scanning fiber projectors will project virtual reality images onto small head mounted rear projection screens mounted at the focal distance required of the optics of the VR goggles. The optics/lenses focus the VR images into the patient's eyes in a way that helps trick the brain into thinking the images are far away.



**Figure 3: Schematic of the proposed scanning fiber virtual reality goggles. From left to right is shown the scanning fiber projecting an image onto a miniature rear projection screen. The person looking into SnowWorld through an optical lens (white lenticular shape near the patient's eye).**

This novel, cost effective, transport Medivac-friendly ruggedized scanning fiber VR goggle prototype will be developed, modified, hardened, and tested by our interdisciplinary team, merging USAISR's VR analgesia team which already includes Dr. Hoffman, in collaboration with Dr. Maani and Dr. Gaylord. This new scanning fiber technology is smaller, lighter, more energy efficient, safe near water, magnet friendly (for fMRI brain scan studies), and has the potential to be further miniaturized via future development to make it uniquely portable in future iterations via congressional funding. Furthermore, these novel scanning fiber



photonic goggles will have richer colors and greater color saturation because each pixel of the photonics goggles is already a color when it comes out of the fiber, unlike typical RGB displays (e.g., LCDs) that use three monochrome color pixels to create one composite colored patch of light. The University of Washington effort will deliver a robust, wide field of view, lightweight VR helmet that is specifically designed to be used by military burn patients and other military and civilian hospital patient populations to reduce pain from recent trauma injuries during transport and during frequent inpatient medical procedures.

## **8.0 CONCLUSIONS**

Excessive acute pain during various medical procedures is a widespread problem in both civilian or military hospitals. The situation becomes more critical when air evacuation is involved since as a precaution to avoid cardiorespiratory problems, patients are too often undermedicated. There must be other ways to alleviate the pain of these patients without using drugs, or at the very least, using the smallest amount of medication in order to limit side effects. Pilot studies run at the Burn Unit of the USAISR show that VR appears to work well for reducing acute pain from combat-related burn injuries. Additional research and development is needed to confirm the efficacy of the treatment and expand the availability of VR not only in the burn and trauma units, but also as close as possible to the front line, e.g., during medical evacuations and eventually even further forward.

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